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Opportunities and Challenges for Bioelectricity in Rural China

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Abstract

Increasing economic growth continues to drive China's growing need for energy. Responding to environment pollution and energy shortage, more and more attention has been paid to biomass-based energy in recent years. As China is rich in biomass resources, biomass resources in rural and the development of bioenergy are introduced briefly. Choosing Laixi County as a case study, the opportunities and challenges for bioelectricity from crop straw are analyzed and discussed. The crop straw production potential for bioelectricity in Laixi is estimated. The establishment of distributed collection spot is more conducive to reducing crop straw collection cost. This method is good for both farmers and power plants. In addition, the current policy schemes on biomass-based energy are presented, and policy recommendations to lower the barriers to bioelectricity development for rural China are discussed.

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Keywords: bioelectricity; biomass; crop straw; policy; rural China

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1. Introduction

1.1. Increasing attention on biomass-based energy

Biomass-based energy is a critical issue worldwide mainly due to growing concern about environmental impacts associated with the use of fossil fuels, national energy security, sustainable use of natural resources, and the need to revitalize rural economies [1, 2]. Bioenergy is one of the most dynamic and rapidly changing sectors of the global energy economy. Conversion of forest and agricultural residues to biomass feedstock for electricity generation and district heating is becoming a common form of bioenergy [3].

The comprehensive utilization of crop straw can not only contribute to the energy supply, but also achieve economic and environmental benefits. Crop straw is an important and potentially carbon-neutral renewable resource. Compared with the same type of thermal power, it is estimated that a 25 million watts biomass-based power generator set can reduce about 100 000 tons per year of carbon dioxide emissions

More and more attention has been paid to bioenergy development in recent years because of its renewability, sustainability, common availability, regional development, rural manufacturing jobs, reduction of greenhouse gas emissions, and its biodegradability. For example, In the 1990s, the US began to fund research programs for evaluation, breeding, and production of perennial bioenergy crops [4]. Valdez-Vazquez *et al* presented the prospects of the crop straw in Mexico [5]. Kukk *et al* evaluated the suitability of growing energy plants on the barren land in Tartu County in Estonia with GIS techniques [6]. Brazil successfully implemented the national ethanol program, which resulted in 4.2 billion gallons of ethanol being produced each year from sugarcane [7].

1.2. Biomass-based energy development in China

Based on the national medium and long term plan of renewable energy development in China, bio-fuel developed from non-food plants is expected to be 12 million tons by 2020, including 10 million tons of bio-ethanol and 2 million tons of biodiesel [8]. In 2008, the total bio-fuel production in China was 1.82 million tons, including 1.46 million tons of bio-ethanol and 0.36 million tons of biodiesel [9]. Between 2004 and 2006, the average annual bioenergy consumption of rural households accounted for nearly 76% of the total rural energy, of which more than half came from crop residues [10, 11], although it made up a small fraction of the country's total energy consumption.

China has listed biomass energy technology research and application as a key area in its Five-Year Plans. Many conversion technologies have been developed to transform crop residues into energy, forage and industrial raw materials, such as direct combustion, gasification and power generation, biogas and biomass liquid fuels [12~18]. The development of biomass power generation sector is faster. China's biomass power generation capacity increased gradually from 1.4 million kilowatts in 2006 to 8 million kilowatts in 2012. The compound annual growth rate is 33.71% from 2006 to 2012.

1.3. increasing crop straw emissions in rural China

As an agricultural country, China is rich in biomass resources. Crop straw is the most part, which accounts for 72.2% in China. And China is one of the most abundant straw resources in the world, producing more than 700 million tons of straw every year, and straw of rice, corn and wheat was 120, 170 and 200 million ton, respectively. The three kinds of straw were about 75% of the total crop straw resources. With the yield per unit increase, the straw total yield will continue to increase in the future.

Direct combustion of straw, primarily through combustion of crop residue for cooking and heating, is still the major source of energy in rural China. This caused many ecological and environmental problems. On one hand, the field burning of crop straw in wide areas results in serious environmental issues [19], On the other hand, it affects air visibility [20] and makes waste of precious biological resource.

2. Case study site introduction

Administered by Qingdao city, Laixi County is located in central Shandong peninsula, China. It has a population of 731,812 in 2010. The total area is 156883.5 hectares, and the most part of land was for agriculture, accounting for 79% of the total.

The main agricultural products of Laixi are wheat, corn and peanuts. In 2010, the city's total area planted crop is 94,100 hectares, which the area land of wheat, corn and peanuts is 47800, 40300, 19200 hectares, respectively. And the total output is 628400 tons which the yield of wheat, corn and peanuts is 88000, 296700, 325100 tons, respectively. The changes in agriculture of Laixi from 2006 to 2010 are listed in Table 1.

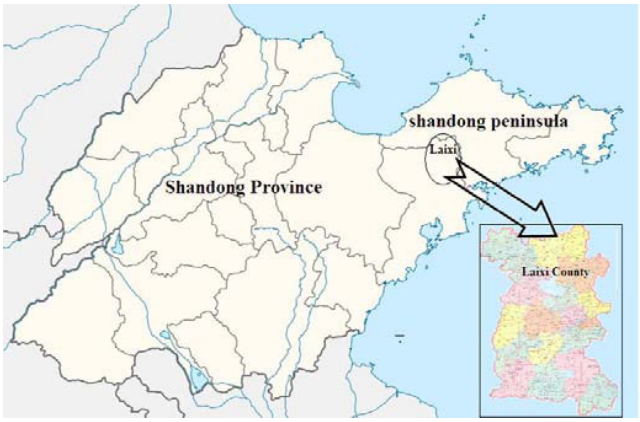

Fig. 1 map of Laixi County

Table 1. Changes in agriculture of Laixi from 2006 to 2010.

	crops area (hectare)	total output (Mt)	wheat (Mt)	corn (Mt)	peanut (Mt)
2010	94051	62.84	32.51	29.67	8.8
2009	91678	59.95	31.39	27.85	8.61
2008	82407	52.35	25.08	25.81	10.13
2007	90607	56.8	28.8	26.81	9.15
2006	85142	53.28	26.67	25.63	9.74

3. The case study of Laixi County

3.1. Basic information about biomass and potential of utilizing biomass for bioelectricity

The total amount of crop straw resources (wheat, corn, peanuts) add up to 595100 tons, equivalent to 303,500 tons of standard coal. Table 2 lists the crop straw resources of Laixi in 2010. Based on the data from table 2, we consider that the amount of crop straw is huge. In other words, the potential of utilizing biomass for bioelectricity is great. The biomass power generation capacity will be 110 million watts.

In 2010, four straw gasification stations are constructed, whose comprehensive utilization of straw is 398 tons and annual output of gas is 796000 cubic meters, equivalent to 478 tons of standard coal.

Table 2. The crop straw resources of Laixi in 2010

Type	Area (hectare)	Yield (Mt)	Ratio of ograin/straw	Theoretical quantity (Mt)	Collection coefficient	Collection potential (Mt)	Equivalent to coal (Mt)
wheat	47800	32.5	0.73	23.7	0.74	15.74	8.03
corn	40300	29.7	1.25	37.1	0.91	33.76	17.21
peanuts	19200	8.8	1.25	11.0	0.91	10.01	5.11
total	-	-	-	-	-	59.51	30.35

3.2. Potential of famers selling biomass to power plant

According to the current 120-200 CNY per ton of purchase price, and the amount available per acre of corn stalks and wheat straw is 0.45 tons and 0.15 tons respectively, the income will increase 90-120 CNY per acre. If 10 acres of arable land per household, in addition to the usage amount of fodder, returning to field and livelihood, the amount of straw available per household is about 6 tons every year. As a result, the income of per household will increase 1000 CNY or so.

Farmers' selling straw not only increases the economic income, but also solves the troubled problems of farmers' dealing with the straw and eliminates the negative impact brought by straw. Increased economic income will greatly arouse the enthusiasm of farmers' selling straw, so the farmers' selling straw is feasible. As a result, the potential of the farmers' selling straw to power plant is available, when the transportation conditions are suitable and the straw purchase price reaches farmers' expect.

3.3. Potential of power plant to buy biomass

The price of the crop straw to the power plant is decided by collecting costs of the straw material from collection radius edge. For Laixi County, the reasonable purchase radius is 50 kilometers.

Unit cost of crop straw to the power plant is a function of unit value of crop straw, the opportunity cost of farmer's labor, fuel price, depreciation cost, maintenance cost, road toll, and transportation distance. Two different collection methods are introduced.

- Method 1: direct collection

  The survey shows that general tricycle can carry around 0.5 tons of straw one time. Now the fuel price 7.5 CNY per liter and the tricycle will consume 5 liters of fuel per 100 kilometers, so the unit kilometer fuel fee is 0.375 CNY; the road toll, depreciation cost and the maintenance cost is 0.15, 0.10 and 0.15 CNY per km, respectively; Labor opportunity costs is 50 CNY per day; unit of straw value is 120 CNY per kg. Collected radius is 50 km. The cost of straw to the power plant is almost 252 CNY per ton.
- Method 2: indirect collection, using distributed collection spot

(1) Purchase price from the farmer to collection spot. The general tricycle is used as transportation vehicle. The cost data is the same as those of method 1. Collected radius is 5 km. The cost of straw to the collection spot is 180 CNY per ton.

(2) Purchase price from collection spot to power plant. The truck is used as transportation vehicle. Its cost is 6 CNY per km which carried 10 tons of straw. The radius distance from collection spot to power plant is 45km. The cost from collection spot to the power plant is 27 CNY per ton.

In summary, the cost of method 2 is 207 CNY per ton. By comparison, method 2 is more cost-effective.

3.4. Barriers preventing biomass electricity generation

The barriers preventing biomass electricity generation include recoverability of straw, increasing purchase price of straw, high fixed and operating cost of electricity generator, the gross thermal efficiency and high energy consumption of electricity generation, electricity selling price in the grid, and so on.

The sufficient crop straw supply is a prerequisite for the steady operation of biomass power plant. Many reasons, such as biomass uneven distribution, the large volume of crop straw, light weight, not suitable for long distance transportation, led to the difficulty of purchase and transport. Inadequate supply and higher transportation costs will restrict the development of large-scale biomass-based power generation in Laixi County.

Biomass power plants have high fixed and operating costs, mainly including in its generator set costs, biomass costs, and operation and maintenance costs. Compared with conventional thermal power, biomass-based plant has twice investment per kW. In addition, the fuel cost and operation and maintenance cost are higher. These led to twice power generation cost of per kW in Laixi County, according to the survey.

Policies for China's biomass power generation are inadequate. There is no specific management system for the life cycle of biomass-based power plant. To support the biomass electricity generation, the authorities have taken different capital subsidies. Nevertheless, the subsidies threshold is too high and procedures are too cumbersome. For

example, according to the Ministry of Finance, enterprises registered capital of 1,000 million CNY and the annual consumption volume of more than 10,000 tons of straw could get a subsidy of 140 CNY per ton. A large number of SMEs cannot have such subsidies [30].

4. Policy analysis

4.1. Current policy schemes on biomass-based energy

China has implemented many policies and principles, including regulations and laws, financial subsidies in order to promote the development of biomass energy. The most important law is the Renewable Energy Law of PRC (RE Law) [21]. Immediately, a series of supporting laws and regulations have been enacted and listed in table 3.

Table 3 Current policy on biomass energy

	law or regulation	Time
1	The Eleventh Five-year development plan for renewable energy [21]	2006
2	Provisional administrative measures on pricing and cost-sharing for renewable energy power generation[22]	2006
3	Finance and taxation support policies on the development of bio-energy and bio-chemicals[23]	2006
4	A Tentative management method of subsidy fund for raw materials base of bio-energy and bio-chemicals[24]	2007
5	National rural biogas service system-building program[25]	2007
6	Medium and long-term development plan for renewable energy in China[26]	2007
7	The Eleventh Five-year development plan of the bio-industry[27]	2007
8	A Tentative management method of special funds for renewable energy development[28]	2007
9	National rural biogas construction plan(2006-2010)[29]	2007

To protect the raw materials supply for the development of the bio-energy and the bio-chemical industry. The government gives subsidies of 180 CNY per acre per agri-field to the raw material base of bio-energy and bio-chemical.

The government gives the subsidized electricity price of 0.25 CNY per kWh for biomass power generation. Since its inception, the subsidized electricity program has lasted for 15 years. In December 2008, the National Development and Reform Commission published the notice which adjusts the subsidy standard to 0.35 CNY per kWh.

4.2. Advantages and disadvantages of current policies

On the basis of a series of supporting policies for biomass-based energy, China's biomass-based energy has made great progress: the number of biomass-based energy projects and the total installed capacity are both increasing each year. In 2010, the total investment of China biomass power plants is about 58 billion CNY with an annual growth rate of 36.7%; the National Energy Board makes a initial plan in the national rural energy meeting, that the biomass power generation capacity will be 13 million kilowatts in 2015 with the annual compound growth rate of 18.77% while it is 5.5 million kilowatts in the end of 2010 [30]. What's more, the current policies will promote the development of many technology advancements and will promote the development of many technology advancements.

However, there are still some disadvantages that need to improve in order to support sustainable development of the biomass-based energy. Firstly, the grid feed-in tariff is too low. The cost of biomass power generation is related to the price of labor, the local biomass fuels market etc. As a result, raw material cost is difficult to be controlled, and leads to the high cost of biomass power generation. At present, our country still has some 50% of the biomass power plant at a loss. Secondly, current subsidy policies cannot bring incentive action for investment. Because it cannot reflect the actual investment cost of grid feed-in projects, neither solve the problems of grid feed-in. Third, Chinese government increases the electricity price subsidy of 0.35 CNY per kWh to encourage the development of

biomass power generation sector. However, the unified subsidy to different types of biomass power generation technology is not beneficial to the development of the diversified technology of biomass power generation, because the different technologies of biomass power generation lead to the different costs and profits.

4.3. Policy suggestions

- on feed-in tariff

According to different benchmark electricity price in different regions, government should provide price subsidy in accordance with same subsidy rate. Local government should solve the problem of grid feed-in in biomass power generation projects and provide price subsidy for the investment of power transmission and the cost of operation and maintenance. According to different biomass power generation technologies, the relevant department should set up a set of cost accounting system for biomass power generation and supply different subsidy.

- on straw material supply

The effective straw collection and storage system need to improve. The government should give subsidies to farmers who take the initiative to collect and sell the straw. The collection agent groups and professional companies are also welcome. In order to reduce raw material costs, optional disorderly competition and prices for straw raw material purchasing are limited. The price mechanism needs to standardize. Road and bridge tolls also should be relieved, and so on.

5. Conclusions

Although the proportion of biomass based power is very small in China's power structures, bioenergy can play a major role in renewable energy development in rural China. As a case study, the current production of biomass in Laixi County is quantified. The results showed that there is potential for Laixi to produce a significant amount of energy from biomass. The opportunities and challenges for bioelectricity from crop straw are discussed. There still exist several barriers to bioelectricity development in rural China. Further study will focus on straw resource structure and resource supply system of biomass power generation sector, location distribution determination for collection spots and power plants, and the detailed investment or financing planning for Laixi County.

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